

THE USE OF A PHOTOGRAPHIC DOUBLET IN CATALOGUING THE POSITIONS OF STARS.

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(Read April 24, 1914.)

In order to utilize for cataloguing and for similar purposes the positions of stars derived from photographs, it is necessary to know the scale of the plates, their orientation and their positions in the sky. In the early days of astronomical photography attempts were made to determine the scale and the orientation by such methods as measuring the absolute focal length of the photographing telescope, and by impressing an orienting star trail upon the plate. These attempts have not been successful and it has now become the universal practice to employ comparison stars for these purposes: that is, stars that appear on the plate with positions known in advance, usually through observations with the meridian circle. Here again experience has shown that in the determination of star places by photography, this matter of comparison stars is usually the weakest link in the chain. For example, in the case of the Astrographic Catalogue much of the relatively high precision with which the plates can be measured is lost on account of the lack of suitable comparison stars.

An experiment that aims to overcome this difficulty is in progress at the Allegheny Observatory. Instead of employing a simple objective to photograph the stars, a doublet lens is used. This has the advantage of much greater extent of field of good definition, at least six times as great as in the case of the objectives used for the Astrographic Catalogue. Consequently in surveying any large area of the sky, plates taken with the latter kind of telescope will require (other things being equal) six times as many comparison stars as the doublet.

The use of the doublet for these purposes was advocated twenty-five years ago by Pickering, but astronomers have feared that the use of such an objective might introduce serious errors of various kinds. The experiments already completed at Allegheny prove that,

with proper precautions, these fears are groundless and that this form of instrument is admirably adapted for cataloguing purposes. The detailed results of these experiments will soon appear as No. 9, Volume 3 of the "Publications of the Allegheny Observatory." On this occasion it will suffice to give merely the results.

A number of regions covering about twenty-five square degrees each, were photographed in duplicate, first with the center of the plate at the center of the region and then with the edge of the plate in that position. A comparison of the two sets of positions gives

$$0''.18$$

as the probable error of the measurement of one image. This quantity includes not only the accidental error but the following as well: (1) outstanding errors in the measuring engine; (2) the optical distortion of the objective, due to a possible failure of the objective to give a truly linear reproduction of the object photographed; (3) magnitude distortion due to spherical aberration and causing bright stars to appear systematically nearer or systematically farther from the center than faint stars. The result shows that all of these errors are very small, and additional experiments indicate independently that (2) and (3) are negligible or very nearly so.

Doublets have been extensively used in astronomy for pictorial purposes. The doublet that we have used for the above experiments differs in one important respect from these: the ratio of the aperture to its focal length is twenty-one instead of five or six. This circumstance is favorable to its performance over a wide field and is doubtless responsible for the smallness of the optical and the magnitude distortions.

Our objective covers well a field of twenty-five square degrees, as compared with four square degrees in the case of the plates for the Astrographic Catalogue. For the latter, as already stated, six times as many comparison stars would be necessary in a large piece of work in order to determine the plate constants equally well. The scale of the astrographic plates is a little more than double that of ours, and the purely accidental error of measurement is therefore somewhat smaller, but not as much smaller as this difference in scale would imply. In practice, so much of the accuracy of photographic positions depends upon the comparison stars, that if a large area

were to be surveyed with both instruments and the same comparison stars were used in the two cases, our doublet would give the more accurate results. If there were at hand in some special case comparison stars that are much superior in number and in accuracy to those that are generally available, then the astrographic plates would give the better positions. Needless to say, a doublet like ours with twice its aperture and twice its focal length would give still better results, but this would necessitate plates about 35 centimeters square and a measuring engine large enough to accommodate them.

Our objective would also be well adapted for compiling zone catalogues of faint stars similar to those of the *Astronomische Gesellschaft*. The latter now extend from 80° north declination to 18° south, a work that has required the cooperation of sixteen observatories during a considerable number of years. Observations are in progress that will extend this catalogue farther south, but no provision has yet been made for the southernmost zones. When these come to be actively considered, the claims for the doublet should be carefully weighed. The original plans for the Gesellschaft Catalogue included the repetition of the observations after the lapse of about half a century. This time is now approaching in the case of some of the northern zones, though others (notably the one between 70° and 75°) are of more recent origin. The repetition of all the northern zones, if carried out photographically by means of a doublet, would be a task well within the powers of a single observatory. Moreover there would be a very considerable gain in accuracy. From the prefaces to the various zones of the Gesellschaft Catalogue we learn that the probable error of one observation in either right ascension or declination is on the average well over $0''.50$. This was derived from observations made with the same telescope on different nights, and does not include certain errors that would be brought out by comparing observations made at different observatories. Our plates yield for the probable error of one observation, $0''.18$. This was obtained by comparing overlapping plates, but it does not include errors due to inaccuracies in the positions of comparison stars.

Although the tests we have made with our doublet may be ac-

cepted as indicating the size of accidental errors and of certain kinds of systematic error, it cannot be claimed that they tell the whole story. To make certain that star places thus derived are free from serious systematic error of any kind, would require much more observational material and would involve certain extensive intercomparisons as well as comparisons with star positions derived by wholly different methods. Such a work is contemplated at Allegheny and is in fact well under way. The zone extending from declination 2° north to $2^{\circ} 10'$ south is being photographed in duplicate, the centers of one set of plates being upon the eastern or western edges of the other. Each plate will embrace 24 minutes in right ascension or 6° ; the program at the telescope therefore calls for 120 plates. To determine the plate constants 602 comparison stars will be employed, an average of ten on a plate. The mean of the two positions for each catalogue star will therefore depend upon about fifteen comparison stars. Thanks to the courtesy and cooperation of Director Campbell and Professor Tucker of the Lick Observatory, the positions of these 602 stars are being determined with the meridian circle of that institution.

Within the limits of declination selected we are measuring the positions of all the stars that appear in the three Gesellschaft zones that overlap. The observing list for the latter was made up of the stars that are designated with (visual) magnitudes 9.0 or brighter in the Bonn Durchmusterung, and as many fainter stars as circumstances permitted. In our work we shall necessarily omit a few stars that are photographically faint by reason of their color, a few stars that are so bright as to present images too large for accurate bisection, and a few doubles that are too close for separation on plates of this small scale. Making allowance for these omissions the completed catalogue will contain about 7,100 stars. It is hoped that this work may not only prove a valuable contribution to our knowledge of the positions and motions of faint stars, but that it may enable astronomers to decide definitely as to the advantages and disadvantages of this form of instrument for the wider applications of the same kind that the future will demand.

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